CORE

Metadata, citation and similar papers at core.ac.uk

Provided by Aquila Digital Community

The University of Southern Mississippi

The Aquila Digital Community

Master's Theses

Summer 8-2011

# A Statistical Examination of Friction Ridge Skin Patterns in the Interdigital, Hypothenar, and Thenar Areas of the Palms

Kristin Ann Pilgrim

*University of Southern Mississippi*

Follow this and additional works at: https://aquila.usm.edu/masters_theses

Part of the Criminology and Criminal Justice Commons

## Recommended Citation

Pilgrim, Kristin Ann, "A Statistical Examination of Friction Ridge Skin Patterns in the Interdigital, Hypothenar, and Thenar Areas of the Palms" (2011). *Master's Theses*. 250.
https://aquila.usm.edu/masters_theses/250

This Masters Thesis is brought to you for free and open access by The Aquila Digital Community. It has been accepted for inclusion in Master's Theses by an authorized administrator of The Aquila Digital Community. For more information, please contact Joshua.Cromwell@usm.edu.

The University of Southern Mississippi

# A STATISTICAL EXAMINATION OF FRICTION RIDGE SKIN PATTERNS IN THE INTERDIGITAL, HYPOTHENAR, AND THENAR AREAS OF THE PALMS

by

Kristin Ann Pilgrim

A Thesis
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Master of Science

Approved:

Thomas S. Pittman____________________
Director

Dean J. Bertram ____________________

Thomas R. Panko____________________

Susan A. Siltanen____________________
Dean of the Graduate School

August 2011

ABSTRACT

A STATISTICAL EXAMINATION OF FRICTION RIDGE SKIN

PATTERNS IN THE INTERDIGITAL, HYPOTHENAR,

AND THENAR AREAS OF THE PALMS

by Kristin Ann Pilgrim

August 2011

Friction ridge skin, which is only located on the fingers, palms, and soles of the feet, has been used in the identification of individuals before the beginning of the twentieth century. A majority of the information known about friction ridge skin has been accumulated through the extensive research of fingerprints. Studies have been conducted to statistically categorize general patterns located on the fingerprints in order to include or exclude an individual for identification purposes. Although fingerprints offer great insight into the importance of friction ridge skin in forensic science, palm print patterns and characteristics have been relatively ignored. Therefore, a statistical evaluation of palm print patterns is necessary to assist latent print examiners in the inclusion and exclusion of prints during friction ridge classification.

ACKNOWLEDGMENTS

I would like to thank Dr. Thomas Pittman for serving as the chair of my graduate committee, as well as for his guidance and advice during my graduate career. I would like to thank Dr. Dean Bertram and Dr. Thomas Panko for serving as members of my graduate committee and for their support and helpful suggestions throughout my research. I would also like to thank Dr. Alan Thompson for his assistance with SPSS and the statistical analysis of my data. Finally, I would like to thank Kristin James for her hard work and assistance during the data collection portion of my research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Figure

# CHAPTER I

# INTRODUCTION

The purpose of personal identification is to connect an individual with a specific attribute based on physical or behavioral attributes and unique to that individual. This type of identification is referred to as biometrics. Biometric techniques include, but are not limited to, facial imaging, voice recognition, and finger and palm print imaging (Ribarić, Ribarić, & Pavešić, 2003). Currently, biometrics is used in forensic science for the identification of criminals (Jain, Hong, & Pankanti, 2000; Liu, Huang, & Hung, 2008; Ribarić et al., 2003; Zhou, Zeng, Lizhen, & Hu, 2002).

The Federal Bureau of Investigation (1972) reports that "fingerprint identification is the most positive form of personal identification known because it is based on the unique and unchanging arrangement of ridge details on a person's fingers" (p. 1). Fingerprints are defined as the patterns that appear on the palmar side of the hand, and they have been accepted as positive proof of identity in forensic science. The use of fingerprints and palm prints in the forensic science field allows certified examiners to classify and positively identify individuals. There are two main uses for friction ridge skin in human identification. The first use is based on record keeping and the ability to determine the real identity of a person. The second use is in criminal procedures (Cowger, 1983).

Classification and identification are often used interchangeably when discussing fingerprints. However, they are two separate and distinct processes. Classification is a step in the identification process. During this process, fingerprints are placed into smaller groups according to similar attributes (Osterburg, 1969). Classification is followed by identification. Print examining compares and matches ridge characteristics in the print in question to known prints until identification or exclusion occurs. There is no specific number of ridge characteristics that must be matched between two prints for conclusive identification. Rather, the examiner must rely on discretion and experience to determine whether a print unquestionably belongs to an individual.

The classification of fingerprints into specific pattern types and characteristics has been a main research focus for many years. To date, however, there has been a scarcity of research conducted on the classification of palm print patterns and characteristics due to the large surface area associated with palm prints. The three main areas of the palm are labeled as the interdigital, thenar, and hypothenar areas. Similar to fingerprints, the friction ridge skin of these three areas has their own patterns and characteristics which can be statistically classified. The classification of palm print patterns and characteristics could be integral to establish a system of palm print comparison and identification can be more useful.

After classification of a print, identification begins. Most forensic research centers on the use of fingerprints for identification. Yet, palm prints have shown to yield just as much information as fingerprints, and can be used to identify individuals. The use of palm prints in forensic science is minimal due to the intense focus on fingerprint research. Increased use of palm prints in forensic science will actively improve identification techniques and procedures in forensic science.

In general, there are three levels of detail that an examiner focuses on during classification and identification of friction ridge skin. The first level of detail is the classification of a print into an arch, loop, or whorl. Once the pattern type has been established, the second level of detail consists of the details of ridge lines. The ridge lines within the pattern may stop, diverge, or split in unique ways. The second level of detail leads examiners to the beginning of the identification phase. The third and final level of detail considered in fingerprint identification is the location of sweat pores within the friction ridge skin which varies between individuals and adds additional identifying features in the print. Once these three levels of detail have been examined, a positive identification may occur (Schwinghammer, 2005). The current research focuses on the first level of detail. The systematic classification of palm print patterns will potentially encourage the use of palm prints for a more efficient identification method.

There are two common types of prints that fingerprint and palm print examiners encounter. The most familiar prints encountered by law enforcement are referred to as latent prints. These prints are a mixture of water, sweat, and oils left on various surfaces through touch. Latent prints can be grouped and classified through the examination of level one details, but these prints can not be identified without “known prints.” Known prints are taken in a controlled setting and rolled with ink or a scanner (Schwinghammer, 2005). It is standard procedure for police departments to fingerprint individuals after an arrest to ensure identity is accurate. Known prints can be stored in filing cabinets or entered into a computer data base for future reference if taken with ink (Bennett & Hess, 2004). Known prints allow fingerprint examiners to compare latent prints from a scene with known prints of specific individuals. If known prints do not possess the same overall pattern characteristics as the latent, the known prints are automatically excluded. Ashbaugh (1992) states “while the classification system is designed to include fingerprints into designated groups, the identification process is designed to exclude these same fingerprints” (p. 506). The current study focuses primarily on the classification of palm prints, which can assist latent print examiners in the inclusion or exclusion of suspects during the identification process.

The purpose of palm print classification is to facilitate identification, which is the same for fingerprints. The classification of palm prints provides potential identification. However, palm prints are much larger than the standard fingerprint and must be classified by dividing the palm into designated areas. The examiner does not need to classify the entire print, only needs the area of the palm in question. Specific areas of the palm can be assumed by the positioning of the print and the ridge flow associated with it (Fisher, 2004).

## Objectives of Study

The main focus of this study is to statistically classify detailed patterns within certain areas of the palms to simplify identification of latent palm prints for certified examiners. In addition, this study compares the pattern characteristics associated with the three areas of the palms in the right and left palms. To ensure this focus is maintained, the following objectives guide this study:

1. Separate palm prints into the interdigital, hypothenar, and thenar areas.
2. Label pattern types located in these three main palm areas.
3. Determine the statistical frequency of patterns in the three areas of the palms.
4. Statistically determine if the frequency of patterns and identifying characteristics differ significantly between the right and left palms.
5. Determine if the results will increase the knowledge of palms prints in forensic science and the law enforcement community.

# CHAPTER II

# REVIEW OF RELATED LITERATURE

## Overview of Friction Ridge Skin

Friction ridge skin is found only on the fingers and fingertips (palmer side), palms, toes, and the soles of human feet. The friction ridge skin allows for a greater gripping ability than that of smooth skin found on the rest of the body (Schwinghammer, 2005). Although its ridged appearance is the most pronounced difference between friction ridge skin and smooth skin, there are additional distinctions. One of the most important distinctions is the nonexistence of hair follicles on friction ridge skin because it does not contain apocrine or sebaceous glands (Cowger, 1983). Smooth skin has eccrine, apocrine, and sebaceous glands, the three major secretory glands of the body. Eccrine glands are located throughout the body but are the only glands found in friction ridge skin. Apocrine glands are found in axillary areas, such as the armpits and genitals while the sebaceous glands are located in areas with hair follicles, such as the face (Lee & Gaensslen, 2001).

In addition, friction ridge skin is thicker than smooth skin (Cowger, 1983). Additional thickness provides greater protection for the hands and feet. It also enhances the sense of touch of friction ridge skin. This provides humans with the ability to differentiate between various surfaces and textures not so easily recognizable using only smooth skin on other parts of the body.

## Formation of Friction Ridge Skin

Friction ridge skin is formed on the fingers, palms, toes, and soles of the feet during fetal development. These ridges are fused together into rows with one pore for each ridge unit (Ashbaugh, 1992). According to Babler (1987), these ridge units are preceded by volar pads that are localized on the fingers and in the interdigital, hypothenar, and thenar areas of the palm. Volar pads are apparent in fetal development around the sixth week of fertilization and are thought to be “the site of initial ridge formation” (p. 297). The location, size, and shape of the volar pads determine the configuration of ridges in friction ridge skin. Heredity plays a part in the development of volar pads, too. However, the location, size, and shape of the volar pads may be altered during development due to various stresses. If this alteration occurs, the volar pads will adjust accordingly and the pattern configuration will be modified during growth. Therefore, it is not the pattern of friction ridge skin that is passed down through heredity, but the shape and location of volar pads (Ashbaugh, 1992).

In a more recent study, Babler (1987) found that it is not necessarily the height of the volar pads that determines the configuration of friction ridge skin patterns. Rather, configuration may be more attributable to the width of the volar pads. In addition, Babler (1978) recognizes the value of encompassing friction ridge growth along with fetal development because it is not a separate and distinct occurrence. The overall development of the fetus also affects the development of the friction ridge skin.

Volar pads continue to grow from the sixth week of fertilization until the eleventh week of development in the basal layer of skin. Between the tenth and eleventh weeks of fertilization, volar pads begin regressing and epidermal ridges start appearing in the basal layer of skin (Babler 1978, 1979, 1987). They are not present on the surface (Babler, 1978). The number of cells that create ridges begins to increase and continue to reproduce between already established ridges after the eleventh week.

Babler (1979) divides epidermal ridge formation into two phases. In the primary ridge formation phase, primary ridges and sweat glands continue to form from the tenth to seventeenth week of development. These primary ridges create a ridge configuration visible on the volar surfaces known as a fingerprint. In the secondary ridge formation phase, no new epidermal ridges are formed. However, secondary ridges lack sweat glands and form in between primary ridges. This process occurs between the seventeenth and twenty-fifth weeks. After twenty-five weeks, “the epidermal ridge system has an adult morphology” (Babler, 1979, p. 200). Once the ridges are formed, they remain permanent until after death and decomposition.

## Friction Ridge Pattern Formation

Ashbaugh (1999) states the purpose of patterns in the friction ridge skin is to resist slippage when in contact with various materials. The patterns created by friction ridge skin depend on the random paths taken by the formed primary and secondary ridges. In addition, Nickell and Fischer (1999) state “all human fingertips have friction ridges, and these ridges form the basis of all fingerprint patterns” (p. 117). The ridges flow in distinctive paths or directions and can be easily recognized by the human eye or through microscopic lenses. Although ridges may take many shapes and paths, ridge characteristics are most often labeled as a ridge ending, a bifurcation, or a dot (Federal Bureau of Investigation, 1972). Ashbaugh (1992) states “the path of the ridges and the shape of the ridges are what cause a distinct pattern that is unique to the individual” (p. 509). In addition, the ridges within friction ridge skin are not parallel lines with a continuous flow (Cowger, 1983). Ashbaugh (1992) elaborates that ridge characteristics are formed when the ridge path suddenly diverges, stops, or changes. For every ridge unit, there is one sweat gland and one pore opening (Ashbaugh, 1999). The location of sweat glands and pores plays a role in the overall pattern of friction ridge skin. The pores located in friction ridge skin secrete sweat that consists predominantly of water but also includes proteins, fatty acids, and lipids (Schwinghammer, 2005). While the current study does not deal directly with specific ridge characteristics or the location of sweat pores, it is essential to acknowledge their importance to understand ridge patterns.

## Premises of Friction Ridge Skin (Fingerprints)

The study of fingerprints is based on three well-established premises. Ashbaugh (1992) states:

> The friction ridge patterns that begin to develop during fetal life remain unchanged during life, and even after death, until decomposition destroys the ridged skin; the patterns differ from individual to individual, and even from digit to digit, and are never duplicated in their minute details; and, although all patterns are distinct in their ridge characteristics, their overall pattern appearances have similarities which permit a systematic classification of the impressions. (p. 505)

These three premises have been tested for the past one hundred years (Schwinghammer, 2005). In addition, they are accepted throughout the forensic science community.

As stated, the first premise defines fingerprints as unchanging and permanent. The friction ridge patterns form during fetal development. After the eleventh week of fertilization, ridge patterns do not change and remain permanent (Babler, 1978). Damage to the friction ridge skin is possible in a variety of ways, including burns and deep lacerations. In a relatively small number of cases, friction ridge damage can be caused by genetics or diseases. Scars are formed in friction ridge skin when there is considerable damage to the deep epidermal layer of skin. Scars tend to cause friction ridge skin to pucker, leaving a distinct and individualizing characteristic. Scarring and genetic or disease damage can provide valuable information in the identification of an individual. If no scarring or damage occurs, fingerprints will remain unchanged from fetal development until after death (Ashbaugh, 1999).

Throughout the history of fingerprint research, no two fingerprints or palm prints have ever been found to be completely identical. Two prints from two different samples are capable of sharing similar attributes. However, research has shown that no two prints have been the exact same on every level of ridge detail (McRoberts, 2005). Pattern shapes and designs share similar characteristics and can appear to be identical on the surface (Ashbaugh, 1992). However, fingerprints and palm prints are so unique that the prints of identical twins are as diverse as prints from unrelated individuals (Jain, Hong, & Pankanti, 2000). Friction ridge skin is the only human attribute that has the capability of precise individualization. Those who have no previous knowledge of the classification and individualization of fingerprints accept this premise as fact (Cowger, 1983).

Although there are numerous theories surrounding the uniqueness of fingerprints, Olsen (1978) considers Charles Darwin's biological variation principle which states that no two things will ever be alike in nature. Statistical and probability research has supported Darwin's principle, and fingerprints are no exception. Many skeptics do not accept the uniqueness of fingerprints because no research has compared a single print to every person in order to test this premise. However, the Federal Bureau of Investigation (FBI) recognizes the emphasis placed on statistics and probability in the field of fingerprinting. Comparing one known print to every individual is not necessary or practical (Federal Bureau of Investigation, 1972). Fingerprints are unique to an individual and even vary between one's fingers and palms.

The last premise states that fingerprint patterns, although uniquely different, can be systematically classified. This classification of fingerprints allows the examiner to narrow the search before beginning the identification process. Fingerprint cards can be filed and searched according to certain classification characteristics (Olsen, 1978). For forensic purposes, fingerprints are classified for two main reasons. The first purpose is to identify criminals within criminal justice correctional facilities. Criminals are fingerprinted in order to correctly identify repeat offenders who tend to use aliases after arrest. The second purpose is to provide a database for offenders who leave fingerprints at crime scenes (Lee & Gaensslen, 2001). Until recently, palm prints have been ignored in the discussion of classification. However, palm prints are unique, permanent, and can be systematically classified. Palm prints are much larger than fingerprints, and offer more detailed information. The current study will focus on the organization of palm prints into a systematic classification for palm print identification.

## History of Fingerprinting

The earliest recognition of fingerprints and palm prints dates back about 10,000 years to the ancient Egyptians. The ancient Egyptians were unaware of the significance of the finger and palm impressions left in mud and clay, but the findings of these impressions opened a new door in the fingerprint world. After a great deal of research, it is now thought that the Chinese may have been the first to be aware of the individualizing characteristics of fingerprints some 5,000 years ago (Lee & Gaensslen, 2001; Nickell & Fischer, 1999; Schwinghammer, 2005; Zhou et al., 2002). Although it can not be definitely proven, the Chinese took considerable caution when leaving fingerprint impressions in clay seals along with individual signatures. One can only speculate why they would leave precise markings on official documents, but these impressions lead researches to believe that friction ridge skin caught the attention of our early ancestors (Lee & Gaensslen, 2001). According to Schwinghammer (2005), the observation and interest in friction ridge skin for identification purposes has developed quite recently, despite such knowledge thousands of years ago.

The earliest recognition of friction ridge skin occurred in 1684 in a paper written by Dr. Nehemiah Grew. Grew was the first to accurately draw and label patterns located in the fingers and palms. He described ridge structure and the location of pores on the ridge units. Grew focused on the classification aspect of fingers and palms, but he did not seem to consider the idea of individuality (Cowger, 1983; Lee & Gaensslen, 2001; Nickell & Fischer, 1999). The research by Grew ignited similar interests in friction ridge skin in years to follow.

G. Bildoo, in1685, and M. Malpighi, in1686, were the next to significantly contribute to the history of fingerprinting. Bildoo concentrated on the anatomy of the human body in his evaluation of ridge units and pore locations. Malpighi took this information further as he researched the actual function and necessity of friction ridge skin. Johannes Purkinje is considered the first person to systematically classify fingerprint patterns in 1823. In his thesis, he established specific rules during individual classification. In 1880, Dr. Henry Faulds wrote his famous journal *Nature*, the first publication that stressed the possibility of using fingerprints as a desirable means of identification. Reports indicate that William Herschel may have been the first to recognize the identification importance of fingerprints, but Faulds was the first to publish research on the topic (Cowger, 1983; Nickell & Fischer, 1999). In 1877, Herschel wrote a letter to the individual in charge of the prison system in India. He stated that prisoners should be fingerprinted to keep track and confirm identities (Lee & Gaensslen, 2001). In addition, Herschel sealed a contract with an ink impression of his hand, and therefore, could be considered the pioneer of fingerprint identification nearly thirty years prior to Faulds' publication (Schwinghammer, 2005).

In 1892, Sir Francis Galton published his book *Finger Prints* after an investigation into the Faulds and Herschel argument. Galton gave credit to Herschel for his work with identification using fingerprints. Galton's book covered almost every topic of friction ridge skin, including morphology, individuality, and permanence. At the same time, Edward Henry took the simplistic ideas of fingerprint classification and created a complex and reliable system which was completed in 1899. The Henry system is still used today for the classification of fingerprints (Cowger, 1983; Nickell & Fischer, 1999).

Before fingerprints emerged as the latest identification technique, the *Bertillonage* system was used. This system was based on the measurements of the human body. Eleven measurements were taken, including the length of appendages and other physical characteristics. These measurements were calculated and the variations of the measurements indicated that the odds of two people having the same measurements were one in 286 millions (Nickell & Fischer, 1999). Fingerprinting soon replaced the *Bertillonage* system primarily because fingerprints were easier to acquire than the numerous measurements of the *Bertillonage* system. The *Bertillonage* system was abandoned in 1903 in the United States, and eventually declined in Europe after 1914 (Cowger, 1983).

## General Patterns Associated with Fingerprints

Fingerprints are grouped into pattern types with similar attributes and descriptors. These relatively large groups of prints can be further placed into subgroups for a more appropriate classification (Cowger, 1983; Federal Bureau of Investigation, 1990). Today, classification is based on the original system created by Edward Henry in 1899. Although there have been some modifications, the general ideas and pattern types remain the same. Henry's system divided fingerprint patterns into three general types. These general patterns include arches, loops, and whorls (Liu et al., 2008; Nickell & Fischer, 1999; Schwinghammer, 2005). In addition, these three general pattern types can be subdivided into eight distinctive patterns. These patterns include the plain and tented arch, the radial and ulnar loop, and the plain, central pocket loop, double loop, and accidental whorl (Federal Bureau of Investigation, 1990; Nickell & Fischer, 1999; Olsen, 1978). Pattern types progress from arches (the most simplistic) to whorls (the most advanced) (Cowger, 1983).

It is important to recognize and differentiate between pattern types and subgroups for classification and identification. General pattern types and subgroups allow examiners to include or exclude a group of prints in comparison to the latent print in question. The easiest way to distinguish between the types of prints is by establishing the number of deltas (or triradii) present (Babler, 1977). The plain arch is the most simplistic of all pattern types. The ridges of a plain arch enter one side and flow towards the opposite end of the impression with a wave appearance in the middle. The tented arch is slightly more complex. The ridges of a tented arch enter the impression on one side and also flow towards the opposite end, similar to the plain arch. However, the wave-like formation comes to a 90° angle, forms an upthrust, or encompasses all the attributes of a loop but one (Cowger, 1983; Federal Bureau of Investigation, 1990; Nickell & Fischer, 1999). Arch patterns are very rare fingerprint patterns.

A loop pattern is more difficult to define than an arch pattern. In order to be considered a loop, the pattern type must have a sufficient recurve, one delta, and a ridge count across a looping ridge (Cowger, 1983; Federal Bureau of Investigation, 1990). Nickell and Fischer (1999) state a looping pattern must also include a core, which is defined as the middle of a print. Ulnar and radial loops share the same characteristics.

The only difference is the direction the looping pattern enters and exits the print. The two long bones of the forearm are the radius and the ulna bones. The radius bone is located on the thumb side, and the ulna bone is located on the little finger side. An ulnar loop flows towards the ulna bone. Therefore, a radial loop flows towards the radius bone (Cowger, 1983; Federal Bureau of Investigation, 1990; Nickell & Fischer, 1999). Loops are the most common fingerprint patterns.

Whorl patterns are the most complex of the fingerprint patterns. For a print to be classified as a whorl, the pattern must consist of two or more deltas with a recurve in front of each and does not adhere to any other pattern definition. Whorl patterns consist of pattern types which can not be included in any other group or category. The plain whorl is the most simplistic whorl pattern. It consists of two deltas and a ridge that forms a complete circuit. This complete circuit passes in front of both deltas (forming a circular pattern). A central pocket loop whorl is more complex. It shares similar characteristics with loops and whorls. The distinguishing characteristic between a loop and a central pocket loop whorl is a second delta near the core of the print. A double loop whorl consists of two separate looping patterns. There are two deltas and two sufficient recurves. The last whorl pattern is labeled as an accidental whorl. Accidental whorls consist of two or more deltas and some other pattern formation (except for a plain arch). This type of pattern is classified as an accidental whorl because it can not be placed in any other category (Cowger, 1983; Federal Bureau of Investigation, 1990; Nickell & Fischer, 1999).

Classification of fingerprints is one of the most important steps towards identification. The previous information of pattern recognition is very general and not inclusive of all pertinent information on the topic. Pattern types are quite unique and small variations occur between them. For this study, it is important to differentiate between arches, loops, and whorls, but it is not necessary to distinguish pattern subgroups.

## Classification Statistics of General Fingerprint Patterns

Arches, loops, and whorls are also known as ridge patterns. These patterns may vary in size, shape, and location depending on the finger and number of ridges (Babler, 1977). Statistical analyses of fingerprints are often applied to include or exclude individuals from certain prints for identification. Currently, forensic fingerprinting relies on the statistical analysis of arches, loops, and whorls during classification to reveal which pattern types occur most frequently and which types are rare.

The different friction ridge pattern types are only class characteristics. This means that any print can be categorized into a certain group, but one cannot be identified until there is a print that can be used for comparison. As previously stated, loops are the most common pattern type and arches are the least common pattern type. These numbers tend to vary, depending on the research. For example, Lee and Gaensslen (2001) state that loops are found 63 percent of the time, and the Federal Bureau of Investigation (1972) states that arches occur only 3 percent in fingerprints. Although there is some variation, the overall consensus is loops are the most frequent, followed by whorls and arches.

Table 1

*General Statistics of Fingerprint Patterns*

| Fingerprint Pattern | Percentage |
| --- | --- |
| Loop | 60 % |
| Whorl | 35 % |
| Arch | 5 % |

Note: Nickell & Fischer (1999); Olsen (1978)

Babler (1978) statistically compared arches, loops, and whorls on specific fingers. In addition, he made comparisons between males and females. The results indicated that in both males and females, ulnar loops are found most frequently on the little finger and less frequently on the middle finger. Radial loops and whorls are found most often on the middle finger in both males and females. Whorl patterns are less frequent on the little finger in both sexes. The major difference arises in the location of arch patterns. In males, arches were most dominant on the index and middle fingers. In females, arch patterns occurred most often on the middle and ring fingers. The most important aspect of such statistical analysis of fingerprinting is to include or eliminate prints in hopes of individualization and identification.

## Overview of Palm Prints

In 1823, Joannes Purkinje accurately described palm impressions. He stated that between the index finger and the thumb are parallel lines that run and diverge throughout the area underneath the digits and above the wrist. He discussed the three areas of the palms and general patterns associated with each. Although he did not explain every detail of the palms, Purkinje may have been the first to focus some research on the importance of palm prints (Lee & Gaensslen, 2001).

The friction ridge skin of palm prints can provide an abundance of information in the forensic community. Palm prints consist of a larger surface area than fingerprints, and can provide analysts with more information in comparison with fingerprints. Although many fingerprint techniques can be used for palm print research, palm print research tends to be more in depth because of the amount of information available within each print. The friction ridge skin of palm prints is unique to an individual and remains permanent through fetal development until decomposition after death (Zhou et al., 2002). However, classification of palm prints is quite different than for fingerprints.

In palm print classification, it is necessary to divide the palm into smaller regions. Unlike fingerprints, palm prints have three main regions with essentially unrelated pattern types. It is possible for patterns to overlap within these sections, but this does not occur very often. Once the palm prints are divided into sections, it is easier to distinguish patterns rather than looking at the entire print (Cowger, 1983). However, the amount of information present in palm prints present statistical difficulty. A statistical evaluation of palm prints for classification and comparison is possible by reducing the palm into smaller portions (Zhou et al., 2002).

Palm prints were not always taken when fingerprints were collected from individuals, so comparisons of palm prints have been a recent development in the last forty years or so. Most objects handled are touched exclusively with the fingers. Palm prints are found mostly on heavy objects that are moved or carried (Olsen, 1978). It is necessary to include palm prints with fingerprint cards in instances where palms would be more predominantly found at a scene.

Palm prints provide just as much evidentiary value as fingerprints in the criminal justice system. In a recent study conducted by Counts (2010), fingerprint and palm print minutia were compared and evaluated. There was no significant difference in the detail found in palm prints and fingerprints. Therefore, palm prints provide as much detail as fingerprints when used for comparisons. Friction ridge skin of the fingers and palms develop in the same unique way, and pattern types within the fingers and palms depend on the development and regression of volar pads. When available, palm prints can offer information during classification and comparison that may be difficult with only fingerprints.

## General Areas of the Palms

The palm can be divided into three areas: known as the interdigital, thenar, and hypothenar. The interdigital area of the palm is located directly underneath the fingers at the top of the palm. The thenar area is considered the part of the palm located on the thumb side (or radial side) of the palm. The hypothenar area is located on the little finger side (or ulnar side) of the palm (Cowger, 1983; Ron Smith & Associates, 1992). These three areas of the palms contain friction ridge skin with distinguishing characteristics and ridge flow.

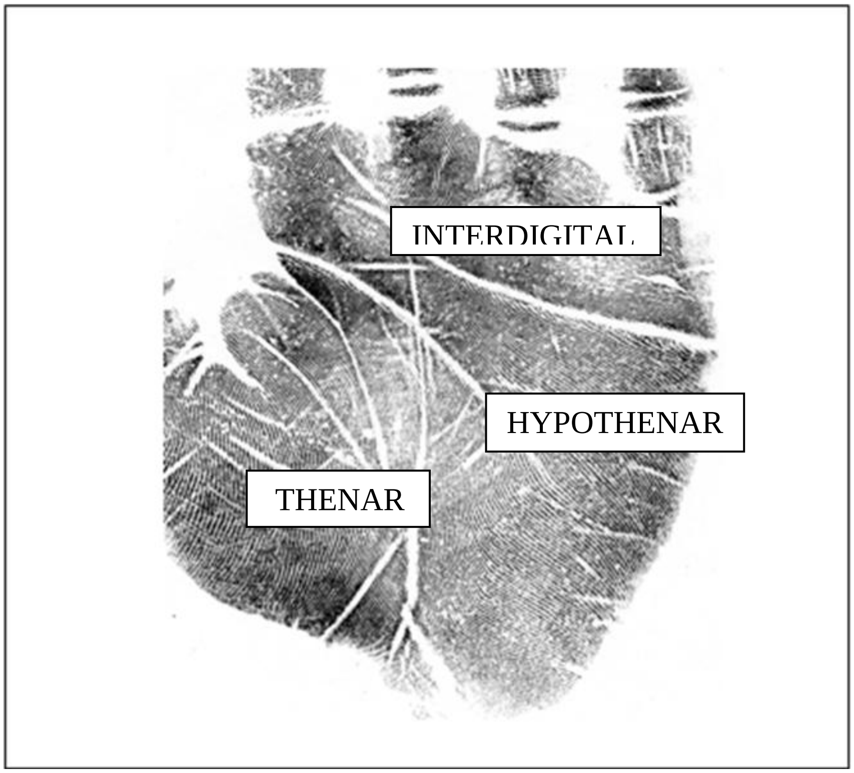


*Figure 1*. Outline of the interdigital, thenar, and hypothenar areas of the palm.

---

Ridge Flow in the Interdigital, Thenar, and Hypothenar

The general ridge flow in palm prints have unique patterns that are found in a majority of palm prints. An understanding of the ridge flow allows for the correct labeling of palm areas, an essential ingredient in palm classification and identification. Research shows that the interdigital area has the most ridge flow characteristics. The greatest number of ridges flow from the base of the index finger towards the ulnar side of the palm and eventually exits the hand. This is known as a “waterfall,” and depending on the hand making the impression, can be labeled as “waterfall right” or “waterfall left.”

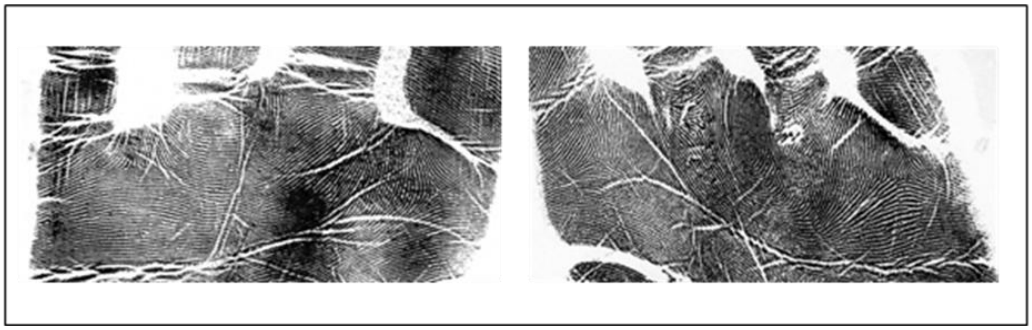

*Figure 2*. Outline of interdigital “waterfalls” in the right and left palms.

The interdigital area is also known for deltas or triradii. This area usually consists of four deltas, but may contain more or less depending on the patterns in the interdigital. According to research findings, loops are the most common pattern found in the interdigital area. Most looping formations start at the base of the fingers, enter the interdigital area, and exit at the base of the fingers. In addition, whorls are often found in this area but less frequently than loops (Ron Smith & Associates, 1992).

*Figure 3*. Outline of a loop and a whorl pattern located in the interdigital area.

The primary ridges in the thenar area of the palm form a semi-circle around the thumb. This is one of the largest ridge flow patterns in the palm and is known as the “half-moon” flow. The thenar area may also consist of an area referred to as a “vestige.” A vestige is a group of ridges that appear to flow in the opposite direction of the rest of the pattern. They run perpendicular to the original ridge flow and are usually found at the top of the thenar area.

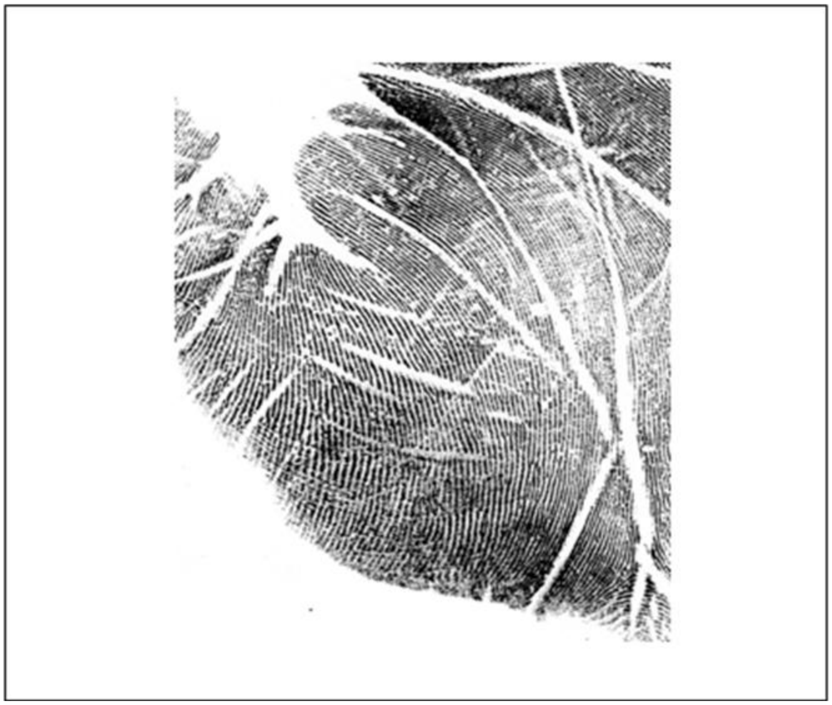

*Figure 4*. Outline of “half moon” ridge flow in the thenar area of the palm.

---

Loop patterns are the most common in the thenar area. However, these loops tend to be more square-shaped than loops found in the interdigital or hypothenar areas. These square-shaped loops are commonly referred to as “long” and “short nose square loops.” Additionally, looping patterns may form that are comparable to regular loops in fingerprints and other palm areas. Whorls are quite rare in the thenar area (Ron Smith & Associates, 1992).

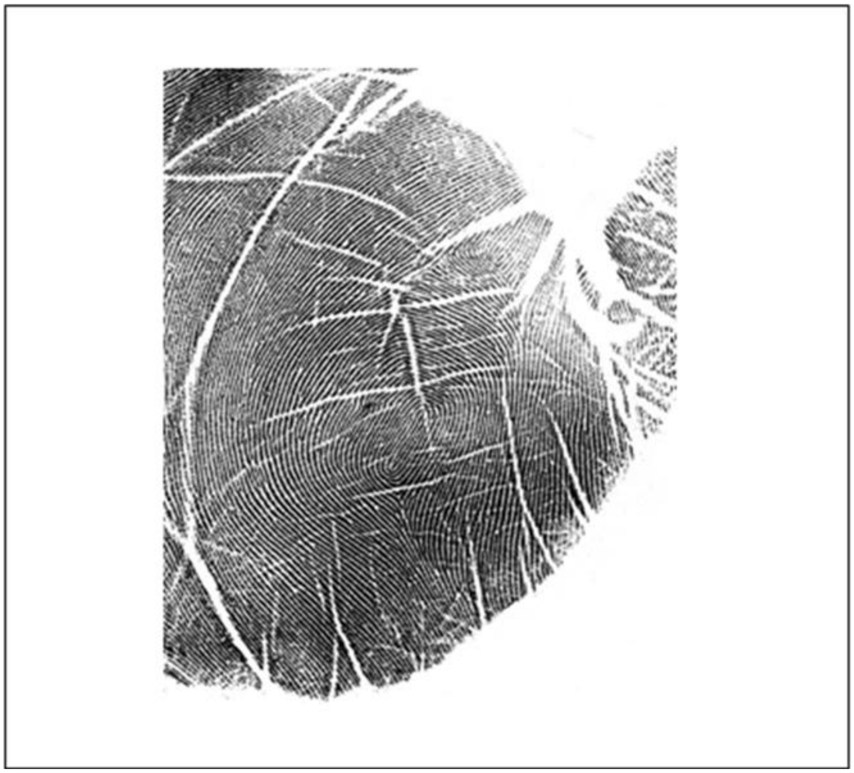

*Figure 5*. Outline of a whorl and a vestige in the thenar area of the palm.

---

The hypothenar area consists of many undisturbed ridges that tend to flow downward from the middle of the hand and exit out the side of the hand towards the little finger (or ulnar). This ridge characteristic is known as the “down and out pattern.” Usually one delta is located in the hypothenar area of the palm, which distinguishes between and ridges of the thenar and hypothenar.

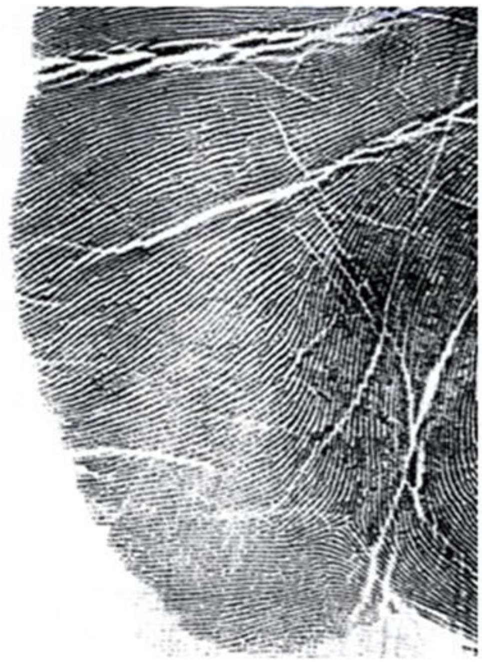

*Figure 6*. Outline of the “down and out” ridge flow in the hypothenar area of the palm.

Similar to the interdigital and thenar areas, looping formations are the most common pattern in the hypothenar. Loops in the hypothenar are labeled as “outward nose loops,” “inward nose loops,” “upward nose loops,” or “downward nose loops.” Outward nose loops are the most common and flow towards the little finger and recurve back into the palm. The hypothenar can include a variety of different pattern types including double loops, whorls, and arches (Ron Smith & Associates, 1992).

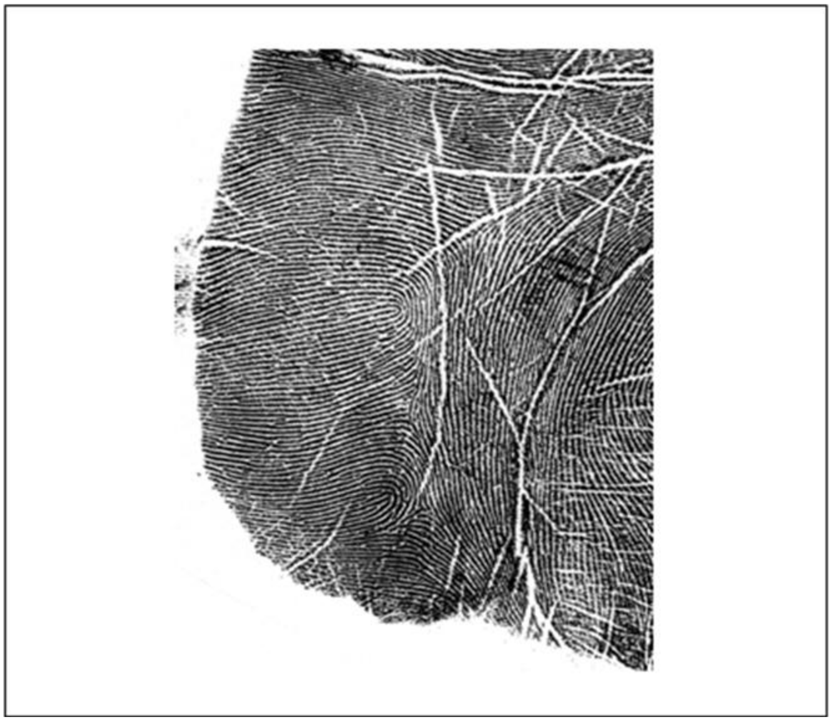

*Figure 7*. Outline of two (2) “inward nose loops” in the hypothenar area.

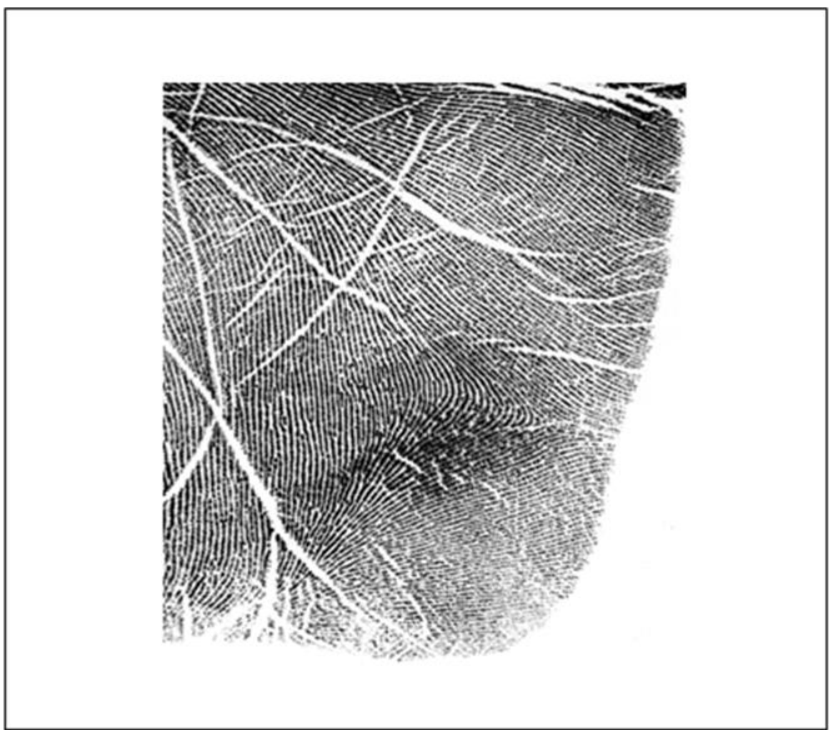

*Figure 8*. Outline of an arch located in the hypothenar area.

An in depth discussion of ridge flow in the interdigital, thenar, and hypothenar is deemed unnecessary in the current research. The current study is focused on the frequency in which patterns (arches, loops, and whorls) are formed in the three main areas of the palms. Although past research has listed loops as the most frequently occurring pattern throughout the palm, there is no statistical data linking loops to palms. A statistical analysis of the frequency of pattern types and the occurrence in right and left palms will allow for classification and eventually easier comparison of palm prints in the future.

# CHAPTER III

## MATERIALS AND METHODS

### Statistical Frequency Analysis

The focus of the current study is to obtain a statistical value for the occurrence of specific friction ridge skin patterns in the interdigital, hypothenar, and thenar areas of the palms during palm print examination. Once the frequencies have been determined, an additional test will be conducted in order to compare the statistical differences between the right and left palms. Due to the lack of palm print research, the study is focused on the review of literature, the different pattern types associated with the three main areas of the palms for classification, and the pattern differences between the right and left palms.

### Palm Print Data Collection

Before statistically evaluating palm prints, data must be collected and organized. The palm prints used in this study were previously collected known prints acquired by Lamar County Sheriff's Office, Forrest County Sheriff's Office, Mississippi Highway Patrol, and Hattiesburg Police Department. Information that could be used in the identification of a person, such as name, race, date of birth, height, weight, social security number, and sex is not present on the known palm print cards selected from the palm print database. Thus, it is impossible to identify a specific individual.

To ensure the integrity of palm prints were suitable for this study, the clarity and overall condition of the prints were taken into consideration. This was the deciding factor in whether a print would be used. The interdigital, thenar, and hypothenar areas of the palms must be clear and rolled properly in order to correctly label pattern types associated with each area. Therefore, palm prints with abnormalities or damage to the entire print were discarded to guarantee satisfactory clarity across the palm print cards. A

"Not Available" designation was given to sections of a print that lacked the clarity of other areas. This was taken into consideration when the data was observed and translated. As previously stated, the palm prints acquired from four law enforcement agencies were kept in a locked and secured location under the supervision of the South Mississippi Bureau of Forensic Services. The use of previously recorded palm prints negated direct contact with human participants.

## Palm Print Pattern Frequencies

Some research has been conducted to determine the frequency of arches, loops, and whorls in fingerprint patterns. However, the frequency of these patterns types located in the interdigital, thenar, and hypothenar areas of the palms has not been explored. Data for this study consists of 10,062 known palm prints. The data recorded from this collection of palm prints was entered, in order, on a data sheet and labeled as Palm (right or left hand), Interdigital Loops, Interdigital Whorls, Thenar Loops, Thenar Whorls, Hypothenar Loops, Hypothenar Whorls, and Hypothenar Arches. The pattern focus in the interdigital and thenar areas consists only of loops and whorls because arches were not found in these areas. The hypothenar area does consist of arches and, therefore, was included in the data. Additionally, it is possible for a pattern to occur more than once in a specific area of the palm (for example, two loops in the interdigital), or for more than one pattern to occur in a specific area of the palm (for example, an arch and a loop in the interdigital). However, this study did not focus on the total quantity of patterns within a specific area but on the frequency of a pattern type within the interdigital, thenar, and hypothenar areas.

Once the data was collected and recorded in an Excel database, the information was labeled accordingly and transferred into a statistical analysis program, SPSS

(Statistical Program for the Social Sciences), to identify the frequency of pattern occurrence. SPSS requires that specific variables be given a numerical value for interpretation. For example, in the variable labeled Palm, the right palm is labeled as “1” and the left palm is labeled as “2.” SPSS utilizes these numerical values to group identical numbers in order to find the frequency. It also makes it possible to conduct additional statistical tests.

Table 2

*Variable Data in SPSS*

| Pattern Identification (Palm) | Value |
|---|---|
| Right Palm | 1 |
| Left Palm | 2 |
| **Pattern Identification (Interdigital Loops)** | **Value** |
| No Loop | 0 |
| Loop | 1 |
| Not Available | 2 |
| **Pattern Identification (Interdigital Whorls)** | **Value** |
| No Whorl | 0 |
| Whorl | 1 |
| Not Available | 2 |

Table 2 (continued).

| Pattern Identification (Thenar Loops) | Value |
|---|---|
| No Loop | 0 |
| Loop | 1 |
| Not Available | 2 |
| **Pattern Identification (Thenar Whorls)** | **Value** |
| No Whorl | 0 |
| Whorl | 1 |
| Not Available | 2 |
| **Pattern Identification (Hypothenar Loops)** | **Value** |
| No Loop | 0 |
| Loop | 1 |
| Not Available | 2 |
| **Pattern Identification (Hypothenar Whorls)** | **Value** |
| No Whorl | 0 |
| Whorl | 1 |
| Not Available | 2 |

Table 2 (continued).

| Pattern Identification (Hypothenar Arches) | Value |
|---|---|
| No Arch | 0 |
| Arch | 1 |
| Not Available | 2 |

Once the pattern information was assigned a distinct and separate value, the values for all 10,062 prints were entered into SPSS. The values were analyzed, their frequencies determined, and the data within the spreadsheet was statistically calculated. This procedure was performed for each category. Frequency values were expressed in percentages and expressed in the frequency of patterns in palm print areas.

Chi-Square Statistical Analysis

After their frequencies were found, a Chi-Square Test was conducted for each of the seven categories (Interdigital Loops, Interdigital Whorls, Thenar Loops, Thenar Whorls, Hypothenar Loops, Hypothenar Whorls, and Hypothenar Arches). The purpose of a Chi-Square Test is to determine whether there is a statistically significant relationship between the right and left palms in each of the seven categories, or if the results occurred by chance. According to Cronk (2008), “a significant chi-square test indicates that the data vary from the expected values. A test that is not significant indicates that the data are consistent with the expected values” (p. 86). Seven null hypotheses were tested using Chi-Square:

1. There is no statistically significant relationship between the right and left palm and the presence of interdigital loops.

2. There is no statistically significant relationship between the right and left palm and the absence of interdigital whorls.
3. There is no statistically significant relationship between the right and left palm and the absence of thenar loops.
4. There is no statistically significant relationship between the right and left palm and the absence of thenar whorls.
5. There is no statistically significant relationship between the right and left palm and the absence of hypothenar loops.
6. There is no statistically significant relationship between the right and left palm and the absence of hypothenar whorls.
7. There is no statistically significant relationship between the right and left palm and the absence of hypothenar arches.

Hopefully, this research will add to the knowledge of palm prints and benefit law enforcement agencies and the forensic science community.

# CHAPTER IV

# RESULTS

## Classification of Patterns in the Interdigital, Thenar, and Hypothenar

As stated in the review of literature, friction ridge patterns are separated into three general pattern types which include loops, whorls, and arches. Each of these three categories can be subdivided into smaller groups with more distinct characteristics. Loops, whorls, and arches occur in both the fingers and palms. However, the friction ridge skin of the fingers has been the main focus in the classification and identification of ridge patterns.

Palm prints consist of a larger area of friction ridge skin and include pattern types similar to those found in fingerprints. The statistical classification of fingerprints has assisted fingerprint examiners in the forensic science community and law enforcement with the identification of individuals. Possibly, the patterns located in the interdigital, thenar, and hypothenar areas can be statistically classified and assist in the identification of individuals.

## Total Pattern Frequencies in the Palms

The total frequency and valid percent of friction ridge patterns in the interdigital, thenar, and hypothenar areas of the right and left palms were calculated (10,062 prints). Loops and whorls were analyzed in the interdigital and thenar areas. Loops, whorls, and arches were analyzed in the hypothenar area. The total frequency of interdigital loops was 9,179, with a valid percent of 91.2. The total frequency of interdigital whorls was 38, with a valid percent of 0.4. In both the interdigital loops and interdigital whorls categories, twenty prints were “not available” due to their inadequate condition during data collection. This accounted for 0.2% of the overall valid percentage for both categories.

The total frequency of thenar loops was 884, with a valid percent of 8.8. The total frequency of thenar whorls was 44, with a valid percent of 0.4. In both the thenar loops and thenar whorls categories, six prints were “not available” due to their inadequate condition during data collection. This accounted for 0.1% of the overall valid percentage for both categories.

Table 3

*Total Pattern Frequencies of the Interdigital, Thenar, and Hypothenar Areas*

| Area and Pattern | Frequency | Valid Percent |
|---|---|---|
| Interdigital Loops | 9179 | 91.2 % |
| Interdigital Whorls | 38 | 0.4 % |
| Thenar Loops | 884 | 8.8 % |
| Thenar Whorls | 44 | 0.4 % |
| Hypothenar Loops | 2992 | 29.7 % |
| Hypothenar Whorls | 61 | 0.6 % |
| Hypothenar Arches | 1065 | 10.6 % |

The total frequency of hypothenar loops was 2,992, with a valid percent of 29.7. The total frequency of hypothenar whorls was 61, with a valid percent of 0.6. In both the hypothenar loops and hypothenar whorls categories, seven prints were “not available” due to their inadequate condition during data collection. This accounted for 0.1% of the overall valid percentage for both categories. The total frequency of hypothenar arches was 1,065, with a valid percent of 10.6. In the hypothenar arches category, eight prints were "not available" due to their inadequate condition during data collection. This accounted for 0.1% of the overall valid percentage for that category.

Pattern Frequencies in the Right Palm

The frequencies and valid percent of friction ridge patterns in the interdigital, thenar, and hypothenar areas of the right palm were calculated (5,031 prints). The frequency of interdigital loops in the right palm was 4,650, with a valid percent of 92.4. The frequency of interdigital whorls in the right palm was 19, with a valid percent of 0.4. In both the interdigital loops and interdigital whorl categories, eleven prints were "not available" due to their inadequate condition during data collection. This accounted for 0.2% of the overall valid percentage for both categories.

The frequency of thenar loops in the right palm was 242, with a valid percent of 4.8. The frequency of thenar whorls in the right palm was 8, with a valid percent of 0.2%. In both the thenar loops and thenar whorls categories, one print was "not available" due to their inadequate condition during data collection. However, his did not affect the overall valid percentage for either category.

The frequency of hypothenar loops in the right palm was 1,534, with a valid percent of 30.5. The frequency of hypothenar whorls in the right palm was 42, with a valid percent of 0.8. In both the hypothenar loops and hypothenar whorls categories, three prints were "not available" due to their inadequate condition during data collection. This accounted for 0.1% of the overall valid percentage for both categories. The frequency of hypothenar arches in the right palm was 584, with a valid percent of 11.6. In the hypothenar arches category, four prints were "not available" due to their inadequate condition during data collection. This accounted for 0.1% of the overall valid percentage for that category.

## Pattern Frequencies in the Left Palm

The frequencies and valid percent of friction ridge patterns in the interdigital, thenar, and hypothenar areas of the left palm were calculated (5,031 prints). The frequency of interdigital loops in the left palm was 4,529, with a valid percent of 90.0. The frequency of interdigital whorls in the left palm was 19, with a valid percent of 0.4. In both the interdigital loops and interdigital whorls categories, nine prints were "not available" due to their inadequate condition during data collection. This accounted for 0.2% of the overall valid percentage both categories.

The frequency of thenar loops in the left palm was 642, with a valid percent of 12.8. The frequency of thenar whorls in the left palm was 36, with a valid percent of 0.7. In both thenar loops and thenar whorls categories, five prints were "not available" due to their inadequate condition during data collection. This accounted for 0.1% of the overall valid percentage for both categories.

The frequency of hypothenar loops in the left palm was 1,458, with a valid percent of 29.0. The frequency of hypothenar whorls in the left palm was 19, with a valid percent of 0.4. The frequency of hypothenar arches in the left palm was 481, with a valid percent of 9.6. In each of the hypothenar loops, hypothenar whorls, and hypothenar arches categories, four prints were "not available" due to their inadequate condition during data collection. This accounted for 0.1% of the overall valid percentage for each category.

Table 4

*Pattern Frequencies of the Interdigital, Thenar, and Hypothenar in the Right and Left Palm*

| Area and Pattern | Frequency | Valid Percent |
|---|---|---|
| Right Interdigital Loops | 4650 | 92.4 % |
| Left Interdigital Loops | 4529 | 90.0 % |
| Right Interdigital Whorls | 19 | 0.4 % |
| Left Interdigital Whorls | 19 | 0.4 % |
| Right Thenar Loops | 242 | 4.8 % |
| Left Thenar Loops | 642 | 12.8 % |
| Right Thenar Whorls | 8 | 0.2 % |
| Left Thenar Whorls | 36 | 0.7 % |
| Right Hypothenar Loops | 1534 | 30.5 % |
| Left Hypothenar Loops | 1458 | 29.0 % |
| Right Hypothenar Whorls | 42 | 0.8 % |
| Left Hypothenar Whorls | 19 | 0.4 % |
| Right Hypothenar Arches | 584 | 11.6 % |
| Left Hypothenar Arches | 481 | 9.6 % |

## Chi-Square Test in Right and Left Palms

As previously stated, a Chi-Square Test was used to determine whether there was a statistically significant relationship between the patterns located in the three areas of the right and left palms. The Chi-Square equation is $\chi^2(df) = \text{Value}, p < \text{or} > .05$

(where df = degrees of freedom, Value = Value of Chi-Square, and p = significance level). If "p" is greater than .05, there is no statistically significant relationship between the patterns in the right and left palms.

The statistical result of the Chi-Square Test comparing the frequency of occurrence of interdigital loops between the right and left palms was ($\chi^2(2) = 19.33$, $p < .05$) and $p = .000$. It was hypothesized that each value would occur an equal number of times (expected count = 4,589.5) and there would be no statistically significant relationship. However, a statistically significant relationship was found between interdigital loops in the right and left palms ($p < .05$). Therefore, the null hypothesis was rejected.

The statistical result of the Chi-Squared Test comparing the frequency of occurrence of interdigital whorls between the right and left palms was ($\chi^2(2) = .20$, $p > .05$) and $p = .905$. It was hypothesized that each value would occur an equal number of times (expected count = 19.0). No statistically significant relationship was found between interdigital whorls in the right and left palms ($p > .05$). Consequently, there was a failure to reject the null hypothesis.

The statistical result of the Chi-Square Test comparing the frequency of occurrence of thenar loops between the right and left palms was ($\chi^2(2) = 201.50$, $p < .05$) and $p = .000$. It was hypothesized that each value would occur an equal number of times (expected count = 442.0) and there would be no statistically significant relationship. However, a statistically significant relationship was found between thenar loops in the right and left palms ($p < .05$). Therefore, the null hypothesis was rejected.

The statistical result of the Chi-Square Test comparing the frequency of occurrence of thenar whorls between the right and left palms was ($\chi^2(2) = 20.59$, $p < .05$)

and $p = .000$. It was hypothesized that each value would occur an equal number of times (expected count = 22.0) and there would be no statistically significant relationship. However, a statistically significant relationship was found between thenar whorls in the right and left palms ($p < .05$). Therefore, the null hypothesis was rejected.

The statistical result of the Chi-Square Test comparing the frequency of occurrence of hypothenar loops between the right and left palms was ($\chi^2(2) = 2.87$, $p > .05$) and $p = .238$. It was hypothesized that each value would occur an equal number of times (expected count = 1,496.0). No statistically significant relationship was found between hypothenar loops in the right and left palms ($p > .05$). Consequently, there was a failure to reject the null hypothesis.

The statistical result of the Chi-Square Test comparing the frequency of occurrence of hypothenar whorls between the right and left palms was ($\chi^2(2) = 8.86$, $p < .05$) and $p = .012$. It was hypothesized that each value would occur an equal number of times (expected count = 30.5) and there would be no statistically significant relationship. However, a statistically significant relationship was found between hypothenar whorls in the right and left palms ($p < .05$). Therefore, the null hypothesis was rejected.

The statistical result of the Chi-Square Test comparing the frequency of occurrence of hypothenar arches between the right and left palms was ($\chi^2(2) = 11.14$, $p < .05$) and $p = .004$. It was hypothesized that each value would occur an equal number of times (expected count = 532.5) and there would be no statistically significant relationship. However, a statistically significant relationship was found between hypothenar arches in the right and left palms ($p < .05$). Therefore, the null hypothesis was rejected.

Table 5

*Chi-Square Test Results Comparing the Right and Left Palms*

| Area and Pattern | df | Value | p |
|---|---|---|---|
| Right/Left Interdigital Loops | 2 | 19.33 | .000 |
| Right/Left Interdigital Whorls | 2 | .20 | .905 |
| Right/Left Thenar Loops | 2 | 201.50 | .000 |
| Right/Left Thenar Whorls | 2 | 20.59 | .000 |
| Right/Left Hypothenar Loops | 2 | 2.87 | .238 |
| Right/Left Hypothenar Whorls | 2 | 8.86 | .012 |
| Right/Left Hypothenar Arches | 2 | 11.14 | .004 |

# CHAPTER V

# DISCUSSION

## Statistical Examination of Patterns in the Interdigital, Thenar, and Hypothenar

The friction ridge skin patterns located on both the fingers and palms provide an individual with an advanced gripping ability. The ridge patterns allow for more traction when handling objects and various surfaces. Because friction ridge skin is thicker than smooth skin, it protects the hands and enhances the sense of touch to differentiate between objects. Friction ridge skin is formed by the fusion of ridges preceded by the location, shape, and size of volar pads. Patterns within the friction ridge skin are formed by the random paths taken by the fused ridges.

Fingerprint analysis is based on three premises. The friction ridge skin of fingers and palms are permanent and remain unchanged until death and decomposition occurs (unless severely damaged). Secondly, fingerprints and palm prints are unique to an individual and may vary between one's own fingers and palms. Finally, fingerprint patterns can be systematically classified. Although fingerprints are unique to an individual, the overall patterns can be classified into similar pattern types which include loops, whorls, and arches.

Palm prints have been relatively ignored when discussing classification. Palm prints consist of a large area of friction ridge skin that can be divided into three smaller areas. These three areas, the interdigital, thenar, and hypothenar, consist of friction ridge skin with unique and permanent pattern formations. Understanding the ridge flow in these three areas and accounting for loops, whorls, and arches permits classification of patterns in the palms. The classification of fingerprints into a system makes it possible for fingerprint examiners and law enforcement officers the ability to include or exclude a print based on its overall pattern type. An obvious advantage of this classification is the reduction in time searching for a match during the identification process. Differentiating between pattern types and “searching smart” makes the identification process less demanding and time consuming.

## Evaluation of Total Pattern Frequencies in the Palms

In the overall classification of fingerprints, loop patterns are encountered more frequently than whorls and arches (loops 60%). Similar to fingerprints, loops are the most frequent pattern found in the interdigital, thenar, and hypothenar areas. The overwhelming majority of interdigital loops may be present in a number of different positions and locations. Their position and location would be more helpful in classification than just the presence of a loop within the interdigital. Loop pattern percentages are drastically lower in the hypothenar and thenar areas of the palm. Therefore, the presence of a loop in the hypothenar or thenar area would greatly reduce the amount of time spent on each known print during identification, thus increasing search efficiency.

Whorls are present in 35% of fingerprints, but are rarely found in the interdigital, thenar, and hypothenar areas. In all areas of the palms, the presence of a whorl allows an examiner to increase search effectiveness from the very beginning, especially if the examiner is able to successfully determine the origin of the print. If the location and orientation of the whorl can not be determined, an examiner has the option of searching the entire known inventory of prints efficiently due to the small percentage of whorls present in the palm.

Arches are the least frequent pattern associated with fingerprints (about 5%). Although arches are not found in the interdigital and thenar areas, the presence of arches exceeds the number of whorls located in the hypothenar area. The presence of an arch in the hypothenar would significantly decrease search time and allow the examiner to search productively during identification.

## Evaluation of the Pattern Frequencies in the Right and Left Palms

Loop patterns are found most often in the three areas of the right and left palms. There is only a slight variation in the valid percentages of loops of the right and left palms in the interdigital and hypothenar areas. Thenar loops provide the greatest difference in pattern frequencies between the right and left palms. While there is a small difference in the frequencies of loops in the thenar, determining whether a loop was created by a right palm or a left palm in the interdigital, thenar, or hypothenar area based solely on the presence of a loop is highly unlikely. Ridge flow characteristics surrounding the loop pattern in all three areas provides greater detail in determining which palm created a given print.

Whorls are the least common pattern type in the interdigital, thenar, and hypothenar. Locating a whorl in any area of the palm increases the search efficiency of examiners. Ridge flow characteristics surrounding a whorl are a better indicator of whether a print came from a right or left palm rather than the presence of a whorl. Arches occur more frequently than whorls in the hypothenar of both the right and left palms. The presence of an arch would increase search efficiency since they are only found in the hypothenar. Similar to loops and whorls, ridge flow characteristics would be the best indicator when determining which palm provided an unknown print.

## Evaluation of Chi-Square Tests in Right and Left Palms

Based on Chi-Square analysis, the null hypothesis was rejected in the interdigital loops, thenar loops, thenar whorls, hypothenar whorls, and hypothenar arches categories.

There was a statistically significant relationship between the right and left palms and the presence or absence interdigital loops, thenar loops, thenar whorls, hypothenar whorls, and hypothenar arches. There was a failure to reject the null hypothesis since no statistically significant relationship was obtained in the interdigital whorls and hypothenar loops categories. Additional research could be conducted to focus on interdigital whorls and hypothenar loops to determine the absence of a statistically significant relationship.

## Overall Evaluation of Palm Print Classification

Palm prints classification has been ignored in previous research. Dividing the palm into the three main regions and assessing each area individually allowed for a systematic classification of patterns in the right and left palms. Loop patterns are most prevalent in the interdigital area, followed by the hypothenar and thenar. Whorl patterns are almost nonexistent in the palms, appearing less than one percent of the time in the interdigital, thenar, and hypothenar areas. The classification of patterns in the palms increases precision and efficiency during the identification process.

The classification of palm prints provides an opportunity for additional research in this area. Creases are an important and generally overlooked characteristic of palm prints. Crease location and appearance can assist examiners in determining which hand a print came from, or narrow the search to which area of the palm produced a print. In addition to the three major creases of the hand, smaller creases throughout the palm have identifiable characteristics. The statistical analysis of palm creases could potentially add to the knowledge of palm print information.

The palm prints used in this study were divided into the three main areas and each area was examined separately. It may be possible, however, to statistically classify the palm as an entity, and determine the collective total of loops, whorls, and arches. In addition, other friction ridge skin formations, such as deltas in the interdigital and vestiges in the thenar, could be statistically analyzed in future research. Although delta formations and vestiges are not considered traditional fingerprint patterns, their location and frequency could provide fingerprint examiners with viable information during identification.

The current study did not account for the presence of more than one pattern in a specific area of the palm. For example, a loop and a whorl can occur in the interdigital area of the palm in the same print, although this frequency is unknown. It is also possible for multiple patterns of one category to occur in one area. For example, two or three “regular” loops may be located in the interdigital area, while the hypothenar area may consist of any combination of loops, including inward, outward, downward, and upward nose loops. The thenar area may consist of long and short square nose loops, as well as “regular” looping formations. An in depth study of the multiple pattern types of each area of the palm may increase knowledge in palm print classification.

This study did not include demographic variables such as sex and race. Frequency differences of palm print patterns between males and females are unknown. Additional research into the race of an individual could provide valuable insights into the pattern differences or similarities between Whites, Blacks, Hispanics, and other ethnic groups. Additionally, this study was centralized in one small geographic location in Southern Mississippi. Expanding the geographical range across the country and possibly across the world can offer more insight into palm print classification.

The most significant statistical finding in this study is the frequency of thenar loops located in the right and left palms. The greatest difference in the other six categories (interdigital loops, interdigital whorls, thenar whorls, hypothenar loops, hypothenar whorls, and hypothenar arches) occurred in interdigital loops, where the right and left palm differed 2.4% from one another (right palm 92.4%, left palm 90.0%). Thenar loops in the right palm occurred 4.8%, and thenar loops in the left palm occurred 12.8%. The 8% difference between right and left thenar loops is significantly more than the other categories. Additional research into the thenar area may be able to determine what caused the variation between the right and left palms.

The statistical examination for classification may lead to more successful and time efficient identification. The increased interest in palm prints potentially allows for a rise in positive identifications, more criminal prosecutions, and overall understanding of the importance of palm print patterns. Since palm print classification is a relatively new analytical tool within the fingerprint community, any additional research and information regarding palm prints would increase its total knowledge database.

# APPENDIX

## IRB APPROVAL

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Institutional Review Board

118 College Drive #5147
Hattiesburg, MS 39406-0001
Tel: 601.266.6820
Fax: 601.266.5509
www.usm.edu/irb

**HUMAN SUBJECTS PROTECTION REVIEW COMMITTEE**
**NOTICE OF COMMITTEE ACTION**

The project has been reviewed by The University of Southern Mississippi Human Subjects Protection Review Committee in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.
  Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: **10110201**
PROJECT TITLE: **Statistical Examination of Data Collected from the Interdigital, Hypothenar, and Thenar Areas of the Palms**
PROPOSED PROJECT DATES: **10/01/2010 to 03/30/2011**
PROJECT TYPE: **Dissertation**
PRINCIPAL INVESTIGATORS: **Kristin A. Pilgrim**
COLLEGE/DIVISION: **College of Science & Technology**
DEPARTMENT: **Criminal Justice**
FUNDING AGENCY: **N/A**
HSPRC COMMITTEE ACTION: **Expedited Review Approval**
PERIOD OF APPROVAL: **11/15/2010 to 11/14/2011**

Lawrence A. Hosman
Lawrence A. Hosman, Ph.D.
HSPRC Chair

11-18-2010
Date

# REFERENCES


Ashbaugh, D. (1992). Defined pattern, overall pattern, and unique pattern. *Journal of Forensic Identification, 42*(6), 503-512.

Ashbaugh, D. (1999). *Quantitative-qualitative friction ridge analysis: An introduction to basic ridgeology*. Boca Raton, FL: CRC Press.

Babler, W. (1977). *The prenatal origins of populations differences in human dermatoglyphics* (Unpublished doctoral dissertation). University of Michigan, Ann Arbor.

Babler, W. (1978). Prenatal selection and dermatoglyphic patterns. *American Journal of Physical Anthropology, 48*(1), 21-27.

Babler, W. (1979). Quantitative differences in morphogenesis of human epidermal ridges. *Birth Defects Original Article Series, 15,* 199-208.

Babler, W. (1987). Prenatal development of dermatoglyphic patterns: Associations with epidermal ridge, volar pad, and bone morphology. *Collegium Anthropogicum, 11*(2), 297-304.

Bennett, W. & Hess, K. (2004). *Criminal investigation: Seventh edition*. Belmont, CA: Wadsworth.

Counts, K. (2010). *Comparison of the biological attributes, first and second level of detail of friction ridge skin of the palms and fingers* (Unpublished master's thesis). The University of Southern Mississippi, Hattiesburg.

Cowger, G. (1983). *Friction ridge skin: Comparison and identification of fingerprints.* New York, NY: Elsevier Science.

Cronk, B. (2008). *How to use SPSS: A step-by-step guide to analysis and interpretation.* Glendale, CA: Pyrczak.

Federal Bureau of Investigation (1972, June). An analysis of standards in fingerprint identification. *FBI Law Enforcement Bulletin,* 1-6.

Federal Bureau of Investigation (1990). *The science of fingerprinting.* Washington DC: Department of Justice.

Fisher, B. (2004). *Techniques of crime scene investigation: Seventh edition*. Boca Raton, FL: CRC Press.

Jain, A., Hong, L., & Pankanti, S. (2000). Biometric identification. *Communications of the ACM, 43*(2), 91-98.

Lee, H. & Gaensslen, R. (2001). *Advances in fingerprint technology: Second edition.* Boca Raton, FL: CRC Press.

Liu, L., Huang, C., & Hung, D. (2008). A directional approach to fingerprint classification. *International Journal of Pattern Recognition and Artificial Intelligence, 22*(2), 347-365.

McRoberts, A.L. (2005). Nature never repeats itself. *The Print, 12*(5), 1-3.

Nickell, J. & Fischer, J. (1999). *Crime science: Methods of forensic detection.* Lexington: The University Press of Kentucky.

Olsen, R., Sr. (1978). *Scott's fingerprint mechanics*. Springfield, IL: Charles C. Thomas.

Osterburg, J. (1969). An inquiry into the nature of proof. *Journal of Forensic Science, 9*(4), 413-427.

Ribarić, S., Ribarić, D., & Pavešić, N. (2003). Mulitmodal biometric user-identification system for network-based applications. *Vision, Image, and Signal Processing, 150*(6), 409-416.

Ron Smith & Associates (1992). *Advance palm print comparison techniques* [Training Handbook]. Collinsville, MS: Ron Smith.

Schwinghammer, K. (2005). Fingerprint identification: How "the gold standard of evidence" could be worth its weight. *American Journal of Criminal Law, 32*(2), 265-289.

Zhou, Y., Zeng, Y., Lizhen, & Hu, W. (2002). Application and development of palm print research. *Technology and Health Care, 10*(5), 383-390.